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J.-C. Lacaze, et al

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[Recherches preliminaires en laboratoire sur des ecosystemes saumatres experimentaux]

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J.-C. Lacaze, C. Hallopeau, M. Voigt*

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Introduction

Methodological research is presently of prime importance in the field of the pollution of marine waters (Fontaine, in printing). One of the problems this research must face is that of choosing appropriate biological material. The selection must contribute a maximum of information for use in explaining the effects of pollution in nature. Initially, we tested radioactive and chemical pollution on plant (Lacaze, 1967, 1969), and animal (Hallopeau, in printing) populations. Today, our primary activity is to show the effects these pollutants have on the biology of experimental marine ecosystems. Numerous attempts already have been made to study aquatic ecosystems under laboratory conditions. Beyers (1963, 1964) has summarized the principle. Samples of the fauna, the flora, sediments, and the water are taken in a natural ecosystem. Containers set up under controlled laboratory conditions receive an equal fraction of each of these elements. Systems such as these, reproduced many times over, then are used for different experiments. This type of ecological research has been dubbed the microcosm method because of the smallness of the systems thus established (microsystems), and because of their isolation from the rest of the biosphere. This research, while it is engaged in an attempt to reach a better understanding of the biology of natural ecosystems, does not imply complete similarity between these latter and experimental ecosystems that

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* Technical collaboration D. Motte.

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stem from them. In the same way that no two individuals of a particular specie are exactly alike, two ecosystems always will be slightly different. Nevertheless, a number of studies confirm the fact that there is a similar evolution between macrocosms and microcosms (Odum et al., 1963; Copeland and Dorris, 1964; Copeland, 1966). Be that as it may, it was not our purpose to reproduce exactly all the aspects of the biology of natural ecosystems. The important thing was the realization of systems with a definite and reproducible structure and functioning. Some authors already have used experimental ecosystems in pollution studies (Fontaine and Aeberhardt, 1963; Copeland and Dorris, 1964; Abbot, 1966, 1967; Hallopeau, in pringint; Lacaze, to be published, b). What we are describing here is the first study (July 1966-August 1967) made to establish the broad outlines of the evolution of several brackish ecosystems under experimental conditions of our own design. The results, we believed, would enable us to select some of the points of the biology of these ecosystems that would be of special interest for our future pollution studies.

Methods

Biocenosis

The biocenosis we studied came from one of the brackish ponds bordering the Arcachon basin (artificial ponds used for pisciculture). These ponds are reservoirs about 500 m long, 10 m wide, with depths from 1 to 1.5 m, and are in communication with the Arcachon basin by a system of locks. All these basins are overgrown by abundant vegetation, providing excellent shelter for the fauna. This vegetation includes the green algae Cladophora, Enteromorpha, Ulva, and Chaetomorpha, and herbariums of the marine phanerograms Ruppia and Zostera. Samples (algae, sediments) were

taken from station P 229 (Amanieu, 1967) in July 1967 (Figures 1 and 2). Salinity in this locality varies between 15‰ and 25‰ over the year. Temperature reaches a maximum, 25°C, in July. Our choice of this type of biocenosis was based on several factors. First of all, we had an established community in a relatively closed environment apparently ready for experimental studies. Then too, its resistance to variations in temperature and salinity also was of interest for preliminary studies. Finally, ecological studies of these reservoirs already had been made by other researchers (Amanieu, 1967; Labourg, 1968, 1969).

Experimental installation and physicochemical conditions

Our experimental installation consisted of a large, air-conditioned room kept at 19°C, in which a series of 3,000 liter plasticized tanks were set up. Each tank was lighted by a bank of four fluorescent tubes (Sylvania gro-lux) providing 3,000 luces of illumination at the surface. The photoperiod was 12 hours. The water added to these tanks was not taken from the brackish Arcachon ponds because they were too far away from our laboratory, but rather from a locality near Cherbourg where the sea water was pumped into a tank truck at high tide and brought to our experimental station. This water was kept in the dark and was heavily oxygenated and filtered constantly for two months. Dechlorinated fresh water then was added to obtain a salinity of 13.5 g/liter, and this was maintained constant by the frequent addition of demineralized water. Oxygenation was provided by two air compressors.

Six kilograms of an equal mixture of the two green algae, Chaetomorpha and Cladophora, were spread on the inside of four trays, made in the form of

rigid plastic frames filled with nylon fiber. Each was immersed in one of the four experimental ecosystems used in this experiment (Figure 3). In addition, the sediments gathered at station P 229 were homogenized, divided into four equal batches, and spread on the bottom of the artificial ecosystems in a layer 1 cm thick.

Salinity, dissolved phosphates (Murphy and Riley, 1962), nitrates and total alkalinity (Strickland and Parsons, 1965) were determined monthly. The development of the principal species introduced into the ecosystems (station P 229, in Amanieu, 1967) was evaluated during the year of experimentation, but provided no basis for detailed quantitative analyses in this preliminary study.

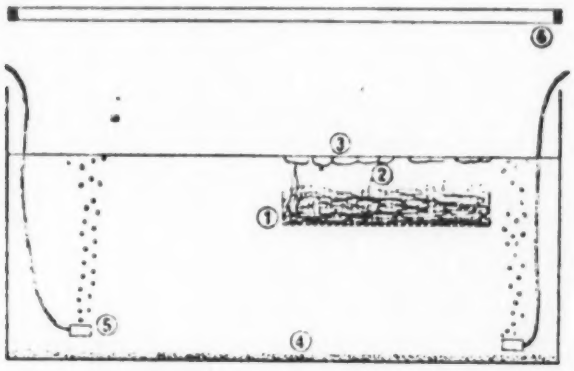

Figure 1. Experimental tank.

1 - algae tray; 2 - Chaetomorpha; 3 - Cladophora; 4 - sediment; 5 - bubbler; 6 - fluorescent tube.

Development of the Ecosystems

Flora

The plant material was represented in the biocenosis by the two macroscopic algae Chaetomorpha lineum Kutz, and Cladophora parriandii Van den Hock.

These algae sheltered an abundant fauna. Over the course of the year of experimentation we observed repeated "blooms" of the blue-green algae Spirulina subsalsa Oerst, which progressively invaded the trays of algae and covered the Chaetomorpha with a thick carpet. Noted as well was a fragmentation and a local decaying of the Chaetomorpha. But these periodic "blooms" did not result in the disappearance of the macroalgae. Three quarters of the initial biomass of the latter were recovered at the end of the experiment. The microalgae were represented principally by the blue-green algae Spirulina subsalsa Oerst, Oscillatoria chalybea Mert, Lyngbya lutea Gom., by the green algae Ulvella sp., Exuviella sp., and by quite numerous diatoms (see p. 10).

A goodly part of the microflora epiphytes of the Chaetomorpha and Cladophora disappeared during the first months of the experiment. A microflora characteristic of a new environment developed progressively on the walls of the tanks, producing a "fouling" community (see p. 10). This fixed microflora (periphyton) included many species, and is of particular interest in pollution studies. The effect of a pollutant can be shown in terms of its biostructure, or its physiology (Lacaze, to be published, a).

Another diatoms community was established in the matting of the blue-green algae Spirulina subsalsa (see p. 12). Characteristic species developed in this microenvironment, one rich in organic matter, originating in particular from the decomposition of some of the Chaetomorpha. Voigt (in printing) has described a new diatom specie that was abundant in this environment.

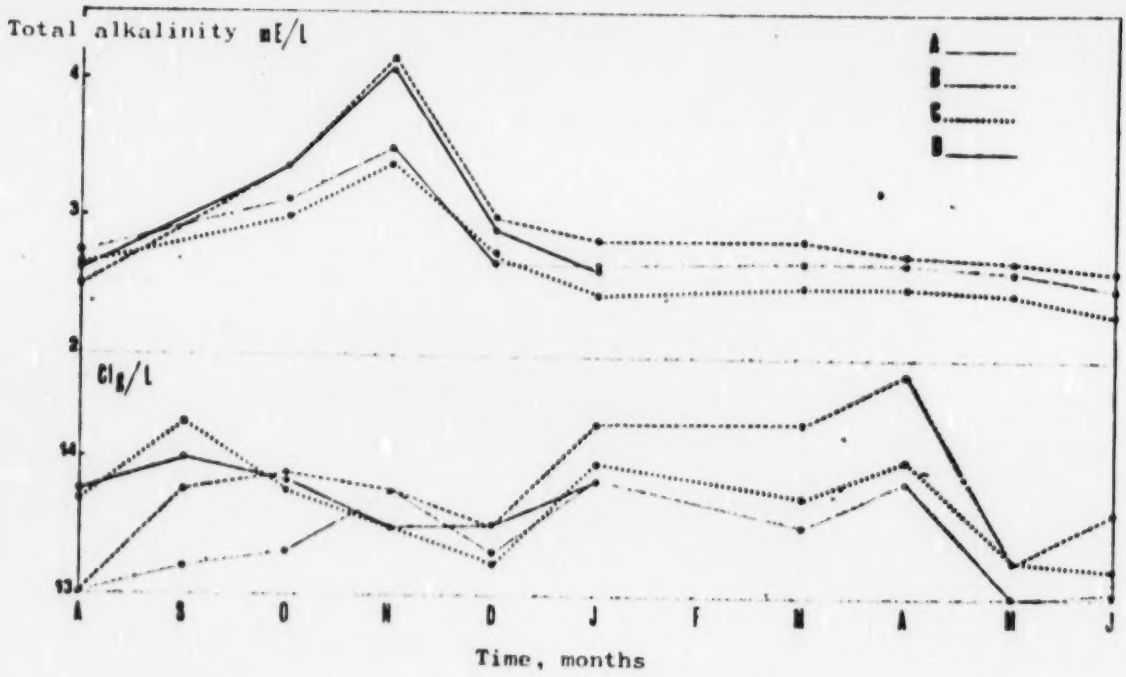

Figure 2. Variation in alkalinity and salinity in ecosystems A, B, C, and D from August 1966, to June 1967.

Fauna

The algae macrofauna was represented by several characteristic species for the whole of the experiment period:

Isopods: Idotea viridis (Slabber); Sphaeroma rugicauda Leach;

Amphipods: Corophium insidiosum Crawford; Erichthonius brasiliensis (Dana); Gammarus aequicauda Martynov;

Gastropods: Hydrobia ventrosa (Montagu);

Lamellibranchs: Cardium edule Linné;

Actiniae: Sagartia sp.

The microfauna was, in large part, composed of very numerous harpacticoid copepods, abundant in all stages; Harpacticus littoralis Sars,

Heterolaophonte stromi (Baird), Ameira parvula (Claus). Included in addition were numerous cilia, nematodes, rotifers, gastrotrichs, acariens, and ostracods. A new specie of gastrotrich was described in the course of taking the different samplings (Renaud-Mornant, 1967).

The year-long period of observations of the macrofauna suggests that all the species brought in with the algae infusions were supported. Still, the adult forms seemed to be less numerous than the young forms (Gammarus, Corophium, Idothea). Furthermore, certain species that showed a poor representation at the beginning of the experiment underwent a dramatic development. Such was the case for the actinia Sagartia sp. Each Sagartia was observed to be surrounded by a heavy growth of blue-green algae, probably the result of an excretion of organic matter by the coelenterates.

Nutrients

The first three months of the experiment was a selection period, characterized by the disappearance of numerous species. As they decomposed, these species released into the environment many nutrients favoring the building of the experimental biocenosis. A Spirulina subsalsa "bloom" appeared between October and December. The environment no longer required phosphates and nitrates during this period. Quite the contrary, alkalinity was a maximum (Figures 4 and 5). The spirulae then continued to play an important role in these biocenoses, causing alternations in periods of growth and degeneration, with variations in the development of algae and phosphate concentrations synchronized. Equally important to note is the parallel evolution of dissolved phosphate concentrations in the four ecosystems.

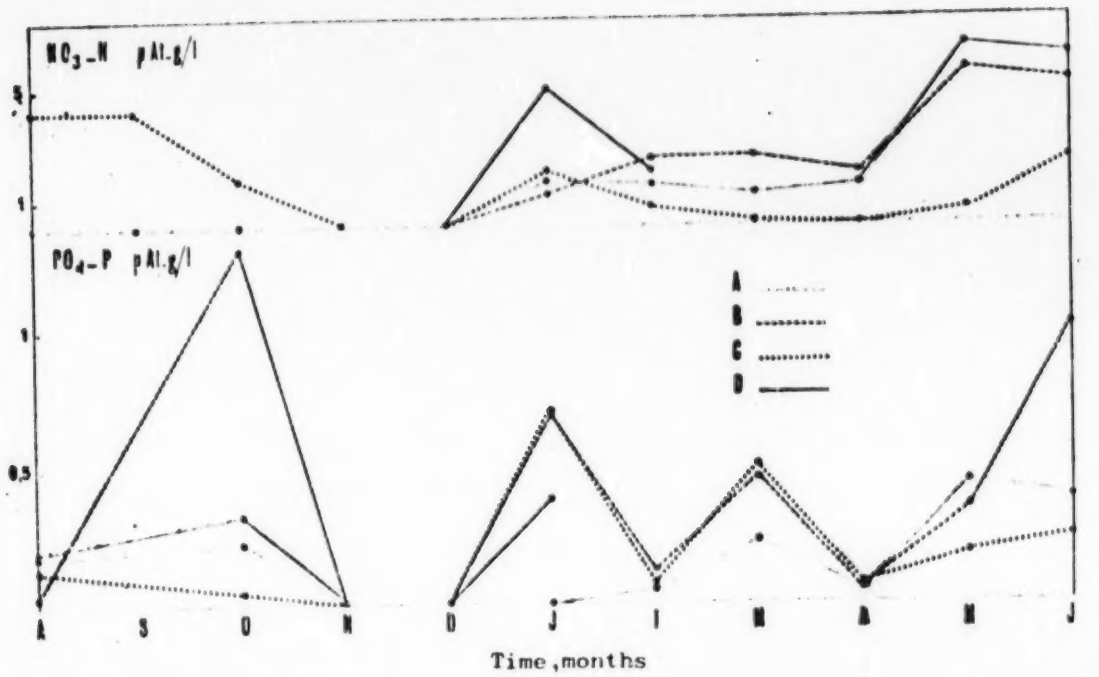

Figure 3. Variations in nitrates and phosphates in ecosystems A, B, C, D, from August 1966 to June 1967. The nitrate content was obtained for ecosystem C only during the first months.

Biostructures of the Plant Material Community

The periphyton and pollution studies

A complete systematic analysis of ecosystems is a practical impossibility. Specie identification generally is reduced to a few groups, simply because of the difficulty in finding a sufficient number of classifications. Moreover, sampling methods themselves are selective in nature. That is why we undertook a detailed, systematic, analysis of only a fraction of the four ecosystems; the diatoms of the periphyton. We thought it would be interesting to use the plant material community for pollution studies (Round, 1965), because such studies are the purpose of our activities.

Stein and Denison (1968) suggest that the periphyton is a better indicator of pollution than the plankton. A fixed community moreover tends to take on an organizational level higher than that of a plankton community (Margalee, 1968). This is a valuable property. The effect of a pollutant on a diversified community seems to us to be much more preferable to the usual tests conducted using isolated species.

Patrick (1954, 1965, 1965) has made fruitful studies of the effect of polluted environments on the biostructure of diatoms communities. The effects of a particular type of pollution generally are to bring about a simplification in the community structure in the form of a decrease in the number of species, each being represented by a large population. In this regard, it is important to point out that pollution does not mandate a decrease in the biomass, but rather quite often brings about an increase in it. This ought not lead to the conclusion that a beneficial action is taking place for, "it is probable that a small biomass made up of numerous species is preferable for the food chain rather than a larger biomass made up of species undesirable as food." (Patrick, 1967). The principal effect of a pollutant is to modify the equilibrium of natural communities. The consequence of the destruction of numerous mechanisms needed for the homeostasis of the biocenoses will be greater instability of these latter.

Study of the diatom microflora

The plant material community

Microscope slides were immersed at a depth of 10 cm when the four ecosystems were established. These artificial substrates became progressively overgrown with algae. Examination for "fouling" in the eartly mouths

months showed it to be almost exclusively the diatom Cocconeis placentula var. euglypta (Ehr.) Grun. This latter seemed to deviate slightly from the normal structure, something that often is the case with the Cocconeis. On eht other hand, the slides that were analyzed after the fourth month (December) showed a much more diversified periphyton. The biostructure of

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Legend for Plate I. A - Place of sampling; Station P. 229; B - Station P. 229: Cladophora on the surface; Chaetomorpha on the bottom.

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this plant material community was persistent for the rest of the experimental period (one year) and there was no significant difference from one ecosystem to another:

c[1]	*Achnanthes brevipes* Ag.
c	*A. brevipes* var. *intermedia* (Kts) Cl.
c	*A. longipes* Ag.
	Actinoptychus adriaticus Grun.
	A. splendens (Shadb.) Ralfs
	A. undulatus Ehr.
c	*Amphiprora decussata* Grun.
c	*Amphora angusta* Greg.
c	*A. hyalina* Kütz
	A. proteus Greg.
	A. ventricosa Greg.
	Auliscus caelatus var. *strigillata* A. Schmidt
c	*Caloneis westii* W. Sm.) Hendey
	Campylodiscus daemelianus Grun.
	C. impressus Grun.
	Ceratoulus smithii Ralfs
	Cocconeis pediculus Ehr.
	C. pellucida Hantzsch
c	*C. scutellum* Ehr.
	Coscinodiscus centralis Ehr.
	C. concinnus W. Sm.
	C. excentricus Ehr.
	Diploneis boyrichiana A. Schmidt
	D. bombus Ehr.

[1] c - common specie; cc - very abundant specie.

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D. didyma Ehr.
D. mediterranea (Grun.) Cl.
Hyalodiscus radiatus Bail.
H. subtilis Bail.
cc *Mastogloia angulata* Lew.
M. braunii Grun.
M. lanceolata Thw.
M. pumila (Grun.) Cl.
M. pusilla var. *linearis* Œstrup
M. pusilla Grun.
M. lacazei Voigt
Melosira sulcata W. Sm.
Navicula cf. *directa* (W. Sm.) Ralfs
N. directa var. *subtilis* (Greg.) Cl.
N. inserata var. *undulata* Hust.
N. mutica f. *cohnii* (Hilse) Grun.
N. palpebralis (Breb.) W. Sm.
N. pusilla W. Sm.
Nitzschia acuminata (W. Sm.) Grun.
N. bilobata W. Sm.
N. cf. *commutata* Grun.
N. cf. *hungarica* Grun.
c *N. navicularis* (Breb.) Grun.
N. punctata W. Sm.
N. punctata var. *coarctata* Grun.
Nitzschia cf. *rigida* Grun.
N. valida Cl. & Grun.
Plagiogramma staurophorum (Greg.) Heib.
c *Pleurosigma elongatum* W. Sm.
Rhopalodia musculus var. *gibberula* Kütz
c *Striatella unipunctata* Ag.
Surirella fastuosa Ehr.
S. crumena Breb.
S. ovalis var. *salina* W. Sm., V. H.
S. striatula Turp.
Surirella sp.
Synedra laevigata Grun.
c *S. laevigata* var. *hyalina* Grun.
Tropidoneis lepidoptera var. *delicatula* Grun.
Triceratium formosum var. *quinquelobatum* Grev.

Community associated with Spirulina subsalsa

The blue-green Spirulina subsalsa developed abundantly after the third month (November) and partially covered, as we have pointed out, the Chaetomorpha and Cladophora on the algae trays. These algae were more or less destroyed. A characteristic flora established itself in the matting of spirulae:

c	*Amphiprora decussata* Grun.
	A. venusta Grev.
c	*Amphora angusta* Greg.
c	*A. angusta* var. *ventricosa* Grun.
c	*A. hyalina* Kütz
	Auliscus caelatus Bail.
	Cocconeis pediculus Ehr.
c	*C. placentula* var. *euglypta* (Ehr.) Cl.
c	*C. scutellum* Ehr.
	Diploneis bomboides (A. Schmidt) Cl.
	D. bombus Ehr.
	D. interrupta (Kütz) Cl.
	Mastogloia adriatica Voigt
	M. adriatica var. *linearis* Voigt
cc	*M. angulata* Lew.
	M. apiculata W. Sm.
	M. lanceolata Thw.
	M. pumila (Grun.) Cl.
	M. lacazei Voigt
	Navicula abrupta Greg.
	N. ammophila Grun.
	N. arenaria Donk
	N. arenaria var. *arcuta* Per.
	N. directa var. *subtilis* (Greg) Cl.
	N. pusilla W. Sm.
c	*Nitzschia navicularis* (Breb.) Grun.
	N. cf. rigida Grun.
	N. sigma var. *hanershawii* Febiger
	N. sigma var. *intercedens* Grun.
	N. marginulata Grun.
c	*Pleurosigma elongatum* W. Sm.
c	*Striatella unipunctata* Ag.
	Surirella ovalis var. *salina* (W. Sm.) V. H.
	Synedra crystallina Lyngb.
c	*S. laevigata* Grun.
c	*S. laevigata* var. *hyalina* Grun.
	Trachyneis aspera var. *intermedia* Grun.

Conclusion

Building experimental brackish ecosystems in the laboratory is not particularly difficult. The algae (Chaetomorpha and Cladophora) bring with them a variegated flora and fauna. There was progressive building of a biocenosis during the first months that was a function of laboratory conditions. Some organisms were destroyed, others developed significantly.

A community was established around the organisms, and diversified.

The following comments can be made after one year of experimentation. The most representative of the species from the brackish ponds introduced with the initial samples are always present. The development of the organisms is similar in the four ecosystems, and this is particularly true of the community of periphyton diatoms. And the evolution of the concentrations of dissolved phosphates is synchronous in the four tanks (Figure 3).

Appreciations

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